HEXTE Observations of SGR 1806–20 During Outburst

D. Marsden and R. E. Rothschild

Center for Astrophysics and Space Sciences, University of California at San Diego
La Jolla, CA 92093

C. Kouveliotou[1],S. Dieters[2]

ES-84 NASA/MSFC
Huntsville, AL 35812

J. van Paradijs[2]

Universitiet of Amsterdam, Astronomical Institute "Anton Pannekoek"
Kruislaan 403, 1098 SJ, Amsterdam

[1] *Universities Space Research Association*
[2] *University of Alabama, Huntsville*

Abstract.
We discuss observations of the soft gamma repeater SGR 1806–20 during the RXTE Target of Opportunity observations made in November 1996. During the ~ 50 ksec RXTE observation, HEXTE ($15-250$ keV) detected 17 bursts from the source, with fluxes ranging from 3×10^{-9} to 2.2×10^{-7} ergs cm^{-2} s^{-1} ($20-100$ keV). We obtained spectra for the brighter HEXTE by fitting thermal bremsstrahlung and power law functions over the energy range $17-200$ keV. The best-fit temperatures and photon indices range from $30-55$ keV and $2.2-2.7$, respectively. The weighted average temperature of the HEXTE bursts was 41.8 ± 1.7 keV, which is consistent with previous SGR 1806–20 burst spectra. The persistent emission from SGR 1806$-$20 was not detected with HEXTE.

INTRODUCTION

Soft gamma repeaters exhibit long periods of quiescence, often spanning years, punctuated by periods of intense bursting activity during which many brief (durations < 1 s) and intense (luminosities L$\sim 1-10^3$ L$_{Edd}$) bursts are emitted by the

source [2]. Believed to be neutron stars, the mechanism(s) for both the steady and bursting X–ray emission is still not well understood ([1]).

SGR 1806-20 is the most prolific SGR, and it has been studied in the X–ray [3], optical [4], infrared [5], and radio [6] bands. The source became active again during the Fall of 1996, emitting many powerful bursts that were first detected with BATSE [7]. A target of opportunity observation by the *Rossi X–ray Timing Explorer* (RXTE) was initiated on November 5, 1996. The data analyzed here were taken during that 50 ks observation, which spanned the time interval starting at 10:53:20 UT (11/5/96) and ending at 10:52:00 UT (11/6/96).

INSTRUMENTATION

The HEXTE instrument [8] aboard RXTE consists of two clusters of collimated NaI/CsI phoswich detectors with a total net area of $\sim$ 1600 cm^2 and an effective energy range of $\sim 15 - 250$ keV. The SGR observations discussed here were taken with the HEXTE in the 16 second rocking mode, in which one cluster is always on the source, with the other pointed off-source for background accumulation. The clusters then beam-switch every 16 seconds, in such a way that one cluster is always locked on-source.

RESULTS

The on-source HEXTE data were binned into a time series for 3 energy bands ($15 - 50$ keV, $50 - 100$ keV, and $100 - 200$ keV). The $15 - 50$ keV time series for each continuous data stretch was searched for bursts using a Bayesian burst search algorithm developed at UCSD. The algorithm calculates the probability of a given number of bursts in each data stretch by incorporating the information on the expected background flux in each time bin. The burst search yielded 17 bursts, all of which correspond to bursts seen by the PCA. The burst times and durations are shown in Table 1, and the lightcurve of two of the brighter bursts (5 & 6) is shown in Figure 1. The durations of the bursts seen by HEXTE ranges from less than 0.1 to 0.6 seconds, and the weakest burst detected by HEXTE corresponds to a PCA count rate of 800 counts s^{-1}.

All of the HEXTE bursts were fit to thermal bremsstrahlung and power law functions using XSPEC, but only the 6 brightest bursts yielded well-constrained spectral fits. In all the burst spectral fits, background was taken from *on-source* data taken immediately preceding and following the burst. The counts spectra were fit over the energy range $17 - 175$ keV, and the resulting best-fit parameters are shown in Table 1. The weakest SGR 1806–20 burst seen by HEXTE has a $20 - 100$ keV flux of 3×10^{-9} ergs cm^{-2} s^{-1}. Co-adding the 11 dim bursts and fitting them with power law and bremsstrahlung functions yields the best-fit parameters $\alpha = 2.05 \pm 0.14$ and $kT = 57 \pm 12$ keV for the mean spectrum of the weak HEXTE bursts. The HEXTE counts spectrum of a bright burst (Burst 2) is shown in

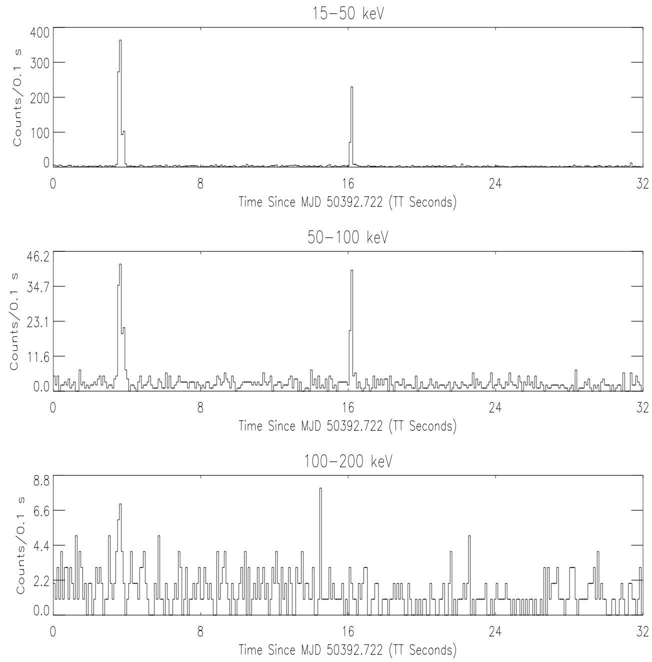

FIGURE 1. The lightcurves of SGR 1806–20 bursts 5 & 6 as seen by HEXTE. The time resolution is 0.1 s bins^{-1}.

Figure 2, with the best-fit thermal bremsstrahlung spectrum overplotted. The χ^2 values were typically large for the stronger bursts, suggesting that more complicated spectral models may be needed to adequately fit the burst spectra.

The weighted mean effective temperature of the six bright bursts and the fit to the mean spectrum of the weak HEXTE bursts is $kT = 41.8 \pm 1.7$ keV. This is consistent with previous measurements of SGR 1806–20 burst temperatures [9]. A chi-squared test for a constant temperature yields ${\chi_\nu}^2 = 3.2$ for $\nu = 6$, or a 0.5% chance that the bursts all had the same temperature, suggesting that there may be some intrinsic variability in the burst spectra.

DISCUSSION

The results of the HEXTE observations of SGR 1806-20 bursts are in general agreement with the durations [10] and bremsstrahlung temperatures [9] obtained by previous observers. The X–ray luminosities $(20-100$ keV) of the bursts, in units of the Eddington luminosity, span the range $L_X \sim 1-50$, assuming a distance to the source of 14.5 kpc [11], isotropic emission, and an Eddington luminosity of 10^{38} egs s^{-1}.

In the future, we plan on using the data from the Proportional Counter Array (PCA) aboard RXTE, in conjunction with the HEXTE data, to fit the SGR 1806–20 burst spectra over the entire $2-250$ keV energy range of the two instruments.

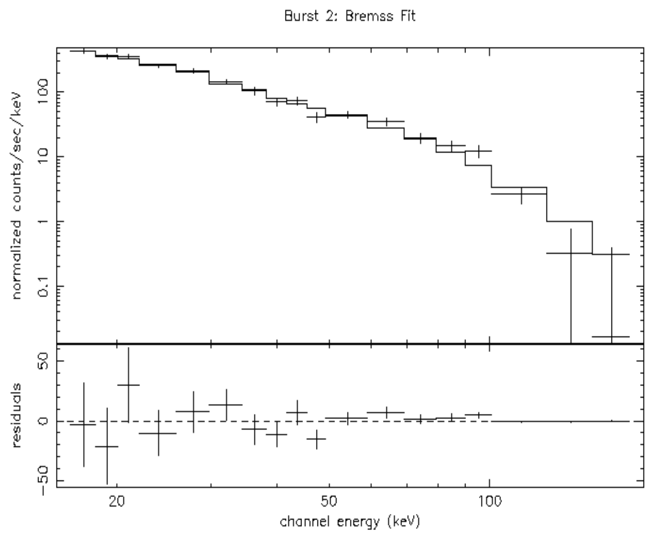

FIGURE 2. The HEXTE count spectrum of a bright SGR 1806–20 burst (Burst 2). The solid line is the best-fit thermal bremsstrahlung model, and the residuals are shown in the bottom panel.

TABLE 1. SGR 1806–20 bright HEXTE bursts

Burst Time[a]	Duration[b]	Photon Index[c]	kT[d]	Flux[e]
0.7106674	0.5	2.29±0.05	51.46±3.30	21.65±0.47
0.7220713	0.5	2.52±0.07	37.62±2.76	12.53±0.68
0.7222172	0.3	2.54±0.12	40.88±4.93	8.9±0.6
0.7306593	0.2	2.16±0.19	54.19±14.47	5.1±0.5
0.8404614	0.4	2.65±0.15	31.06±4.50	8.7±1.0
1.1905632	0.3	2.32±0.14	45.67±7.85	10.86±0.11

[a] Terrestrial dynamical time (MJD modulo 50392)
[b] Seconds
[c] Power law fit
[d] Thermal bremsstrahlung fit (keV)
[e] $20 - 100$ keV flux (10^{-8} ergs cm^{-2})

This will result in a more accurate determination of the continuum spectral shape of the SGR bursts.

Acknowledgements. We thank NASA for support under grants NAS5-30720 (D.M. and R.E.R.), NAG5-2560 (S.D. and C.K.), and NAG5-4878 (JvP)

REFERENCES

1. Thompson, C. & Duncan, R. C. 1995, *MNRAS*, 275, 255
2. Norris, J. P. et al. 1991, *ApJ*, 366, 240
3. Sonobe, T. et al. 1994, *ApJ*, 436, L23
4. van Kerkwijk, M. H. et al. 1995, *ApJ*, 444, L33
5. Kulkarni, S. R. et al. 1995, *ApJ*, 440, L61
6. Kulkarni, S. R. et al. 1994, *Nature*, 368, 129
7. Kouveliotou, C. et al 1996, *IAUC*, 6501
8. Gruber, D. E. et al. 1996, *Astronomy & Astrophysics*, 120, 641
9. Atteia, J. L. et al. 1987, *ApJ*, 320, L105
10. C. Kouveliotou 1995 in "Towards the source of GRBs", 29th ESLAB Symposium, 49-56
11. Corbel, S. et al. 1997, *ApJ*, in press